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Research paper

Development of the Heater for Flat Panel Display Manufacturing Process using Control Zone Reduction and Self-Temperature Compensating Technology

Hyoung-Keun Park[1]*

[1]Dept. of Electronic Engineering, Namseoul University,
**Corresponding author E-mail: phk315@nsu.ac.kr*

Abstract

Conventional control technology of far infrared ray heater does not apply the rule of heater map (heater combination) according to the enlargement of glass due to weak pattern design technology of heater, and it is arbitrarily combined with designers or customers according to the tendency and demands. That is, the heater pattern designer and the technical skill of the customer can cope with the division of the general control zone number without considering the correction ability according to the heat sink amount. In this study, by using the patterning technology of the heater using the surface Temperature Coefficient of Resistance (TCR) of the heater, the technology capable of dramatically reducing the number of control zones is obtained by securing the design ability to perform the temperature correction by itself. In addition, since the Argent-Palladium (Ag-Pd) of the resistor has a TCR characteristic about 10 times that of the nichrome, the self-temperature correction is performed in the heater plate by effectively patterning the resistor of the high TCR. Therefore, we developed a hot plate oven using a steel heater as a solution to solve the problems of the glass curing device which is indispensable for the Liquid Crystal Display (LCD) and Organic Light Emitting Diode (OLED) manufacturing process and satisfy the needs of the customer.

Keywords: *Control Zone Reduction; Flat Panel Display Manufacturing Process; Hot Plate Heater; Far Infrared Ray Heater; Self-Temperature Compensation*

1. Introduction

The curing devices used in the existing Flat Panel Display (FPD) manufacturing process include hot plate and hot air, and infrared (IR) oven using far-infrared ray heaters. These heat source and IR devices limit temperature control, manufacturing cost, production speed, particle generation, and hume removal as glass of flat display becomes larger.[1-4] In particular, the surface of the glass is divided into areas of at least 20 zone to ensure uniformity of the temperature according to the formation, thus controlling the temperature of each area. In addition, as the number of areas increases as the size of the hot plate increases, there are many problems, such as upgrading the design of the hot plate oven and handling complex connectors.

2. Conventional Heater Analysis

2.1. Conventional Heater

Conventional heaters are generally hot plate as shown in Fig. 1, the hot plate heater works is shown in Fig. 2, Fig. 3. The conveyor drying oven is shown in Fig. 4, the order of operation is shown in Fig. 5, the temperature variation inside the heater according to the distance is shown in Fig. 6.

The generally hot plate heater shall implement Solid State Relay (SSR)/ Silicon Controlled Rectifier (SCR) control unit for increasing the number of control zones and controlling the temperature. In addition, an increase in the number of wires and terminal controllers (TCs), a separate structural design is required for handling the cables, and a rise in particle and poor performance due to the use of ceramic tubes may reduce yields and cause a temperature imbalance in the heater plate.

Fig. 1: Generally hot plate heater

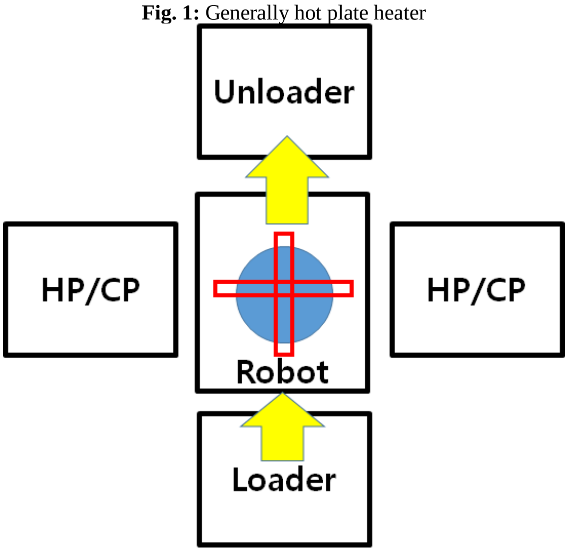

Fig. 2: Generally hot plate heater process (loading and unloading)

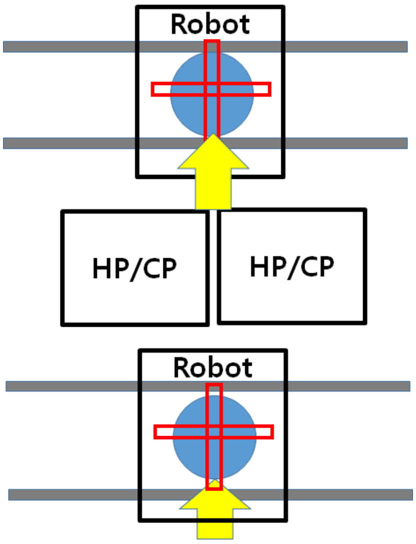

Fig. 3: Generally hot plate heater process

Fig. 4: Generally conveyor oven heater

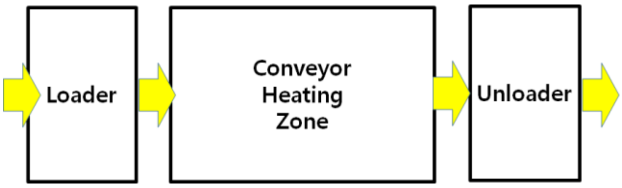

Fig. 5: Operation order of generally conveyor oven heater

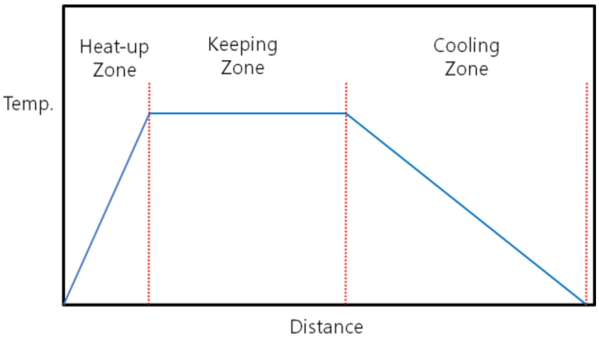

Fig. 6: Temperature variation inside the heater according to the distance of generally conveyor oven heater

2.2. Problems with Conventional Products

As the glass size becomes larger, the number of control zones to achieve temperature uniformity increases. And due to difficulties in implementing SSR / SCR control unit for temperature control and the increased cost, the cost of heater manufacturing has increased dramatically and the product quality has decreased. Also, the heater surface becomes more complex, the number of wires and TCs increases, and a separate structural design is required to handle the cables.

In the process of high temperature, the wires are located within the plate, so the ceramic tubes must be used for protection of the wires. For this reason, the additional process and ceramic yield must be increased. Therefore, by employing a method to divide the zone to secure the temperature uniformity, the number of control zones increases and causes temperature imbalance in the side of the heater. To solve these problems, a new self-temperature adjustment function is used to secure temperature uniformity, to apply hot protection power terminal technology to the cable-free room inside the chamber, vacuum and plasma environment. Therefore, in this study, a hot plate with steel head was developed to solve problems of glass curing devices that are essential for manufacturing process of LCD and OLED and to satisfy client needs.

Table 1: Products Analysis

Company & Product	AVACO	Osung LST	Vessel
Product Name	Oven	Hot plate	Conveyer drying oven
Heat source	Sheath heater	Sheath heater	IR lamp heater
Application	LCD/OLED	LCD/Secondary cell	LCD
Temperature	Within 230℃	Within 230℃	Within 250℃

In this study, we produced a small size (Gen 2) second stage demo oven to test the feasibility of this development. The test results give excellent results that can be applied up to 350 ± 1.5 ℃. Through this process, we secured a technology for achieving temperature uniformity by applying core technology such as reduction of control zone number and outsourcing technology of power and manufacturing of FPD (LCD / OLED).

Table 2: Control Zone Technique Analysis of FIR heater

Company & Specification	AVACO	Vessel	YEST
Glass size	2,200 * 2,500mm		
Heater size	Within 2,500 * 2,900mm		
Control Zone	20 zone (Top and lower 10 zone)	16 zone	16 zone
Temperature range	230℃ ± 5℃	350℃ ± 15℃	350℃ ± 12℃
Heat source	Sheath/FIR Plate heater	Sheath/FIR Plate heater	Sheath/FIR Plate heater

3. Heat Sink Reduction and Self-Temperature Compensating

3.1. Heat Sink Reduction Technology

Heat sink occurs due to the systematic structure and space of the chamber when using the inside of the chamber at high temperature. Even if the actual amount of heat produced by the heater is the same by thermal insulation technology, anti-conduction technology, and free space of infrared rays, thermal imbalance is achieved by the above factors. In addition, the heat generation area is expanded since conventional heaters must be combined to increase the area of the heater. In proportion, heat flow in the outer part increases compared to the central part, resulting in heat island. Therefore, it is necessary to understand these heat characteristics and to design techniques that take into account the amount of heat sink from the mechanical design of the chamber. In addition, after the device is completed, process technology is needed to correct the amount of heat sink depending on the results of the thermal profile due to the device and the systematic characteristics.

3.2. Reduced Control Zone and Self-Temperature Compensating Technology

Traditional control technology for far-infrared ray heaters makes the design of patterns weak, preventing the application of certain rules of heater map (heater combination) due to the large scale of glass, and made by the designer or customer. In other words, the heater pattern designer or the client's technical skills do not take into account the ability to compensate the amount of heat sink as shown in Fig. 7, and respond by dividing the normal number of control zones.

Therefore, this study proposed a pattern technique for the heater using the surface TCR characteristic and reduced the number of controls zone by securing design capability for temperature compensating on its own.

Ag-Pd of a resistance object has about 10 times the TCR characteristics compared to nichrome, effectively pattering the high TCR resistance object. This enables self-temperature compensating and temperature uniformity of wide area within the heater plate. Fig. 8 is a conceptual diagram of self-temperature compensating.

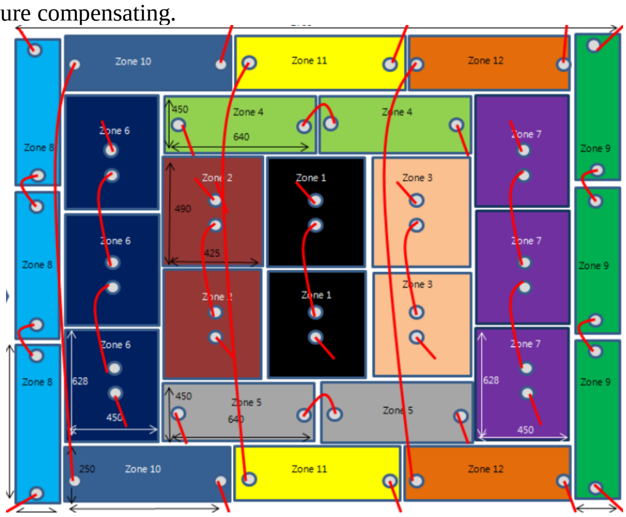

Fig. 7: Example of 12 zone heater combination

When you turn on the power in the picture, heat is concentrated in the center. (①, ②) As the resistance of the heated b increases and the current becomes difficult to flow, the temperature of b decreases. In other words, the brake is automatically applied to the heater and a and c are relatively susceptible to flow, increasing the temperature. (③) Conversely, when a and c get hotter than b, the resistance values of a and c increase, thereby lowering the temperature by limiting the flow of current, and b raises the temperature by relatively allowing the current to flow.(④) Therefore, temperature can be uniform through pattering of material properties effectively.(⑤)

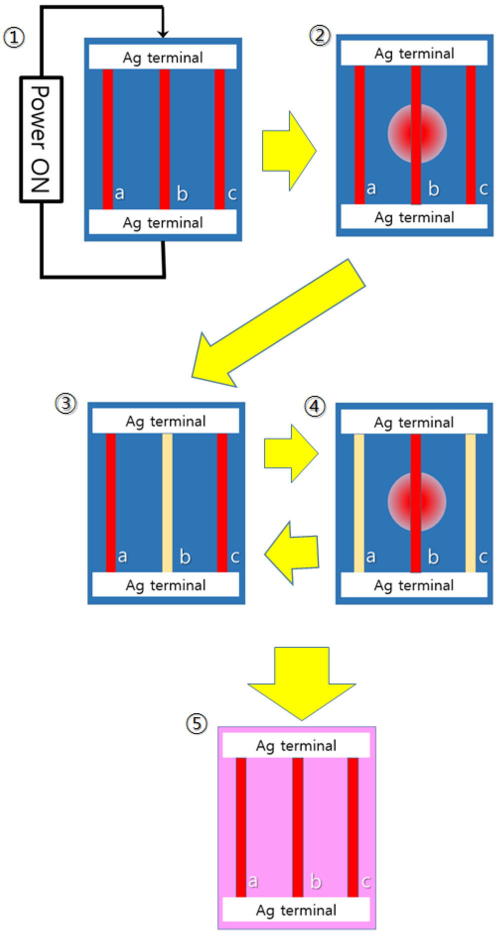

Fig. 8: Conceptual diagram of self-temperature compensating

4. Analysis of the Proposed and the Conventional Heater Design Features and Characteristics

4.1. Power Unit Externalization Processing

The larger the glass size, the higher the number of divisions (between 24 and 32) of the heater is used, and the greater the control zone is. Therefore, there are many problems as wires and TC lines are complicated inside the plate and connected externally through the plate. This means that the electrical temperature of the wires in the hot process is weak, so the sheath must be removed and ceramic tubes are inserted, or the power supply bar must be connected with a long length inside the heater. This method creates many problems in product design and assembly because of the complexity of particle and devices. In addition, the power supply is processed externally and the wires are not exposed inside the plate to solve the problems caused by a vacuum wire and an induced current generated from the heater surface. This allows the electric wire to be used directly at high temperatures, regardless of process temperature, and prevents the wire itself from being used by using the power booth bar as shown in Fig. 9, Fig. 10.

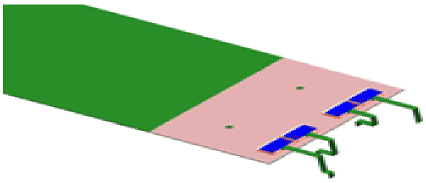

Fig. 9: Structure of power unit booth bar

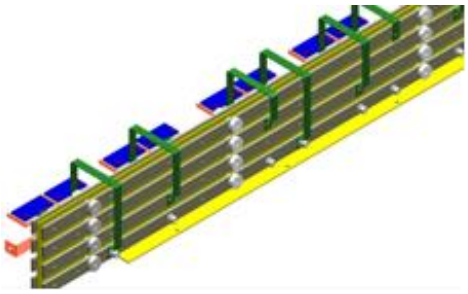

Fig. 10: Heater power unit externalization

4.2. Chamber and Instrument Design

In order to develop basic design technology to reduce control zone according to the trend of large glass size, demo product was developed in 2nd generation size and the design technology was secured based on the successful design of 6 Generation (6G).

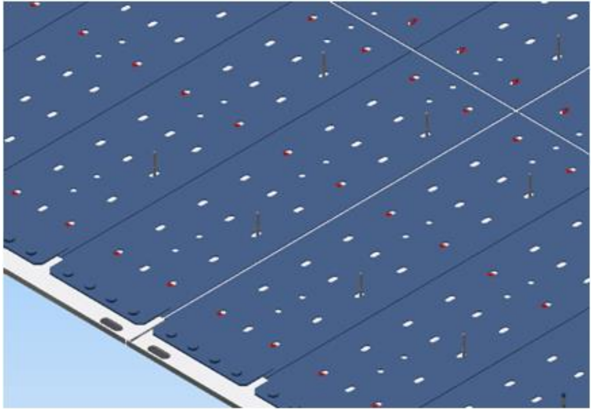

Fig. 11: Heater plate and lift pin structure

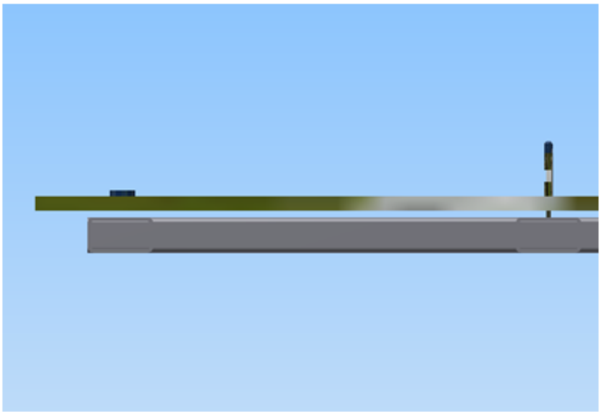

Fig. 12: Vertical structure of heater and reflector

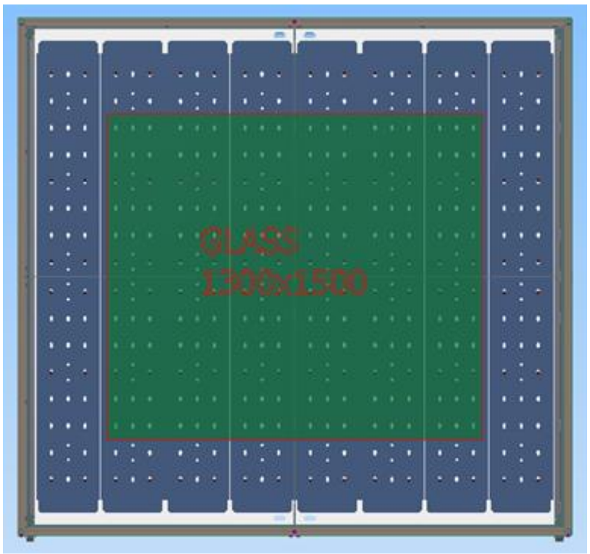

Fig. 13: Heater layout

4.3. Comparative Analysis of Heater Maps and Control Zones

Conventional heater specifications are number of zones and temperature uniformity : 12 zones and 230℃ ± 5℃, combined heater number : 28EA, number of wires used : 56 wires and TC number : minimum 12 set, required for Process Identifier (PID) control by number of control zones

Comparison of characteristic according to the control zone of the conventional heater. Complex combinations of heaters, problems with wires escaping through plates, and excessive control zone require a lot of PID control, which requires a lot of additional expenses. The control ZONE is segmented, which also takes a lot of time during the temperature optimization process, and takes a lot of time to install and set up. In case of high temperature oven, as the hot standard of electric wires is low, there is an inconvenience that should be used by removing the sheath and using ceramic tubes as cover. The ceramic processing cost of the power terminal is very high due to the segmentation of the heater (using dual cover of the power unit).

6G heater specifications are number of zones and temperature uniformity : 5 zones and 350℃ ± 3℃, combined heater number : 14EA, number of wires used : by placing the power terminal on the outside and implementing it as a power port bar, possible to free wire and TC number : minimum 5 set, required for PID control by number of control zones

The characteristics of the 6G heater map and control zone are as follows. The wires are located on the outside and are connected and connected vertically by the extension board, thus preventing as aching and allowing for use without wires. And individual heaters are divided into small cells, and each cell is connected in parallel to take full advantage of the temperature adjustment function using TCR characteristics. Also, inside the hot plate for use only with high temperature wires up to the heater's guaranteed temperature designed so that no wires exist in

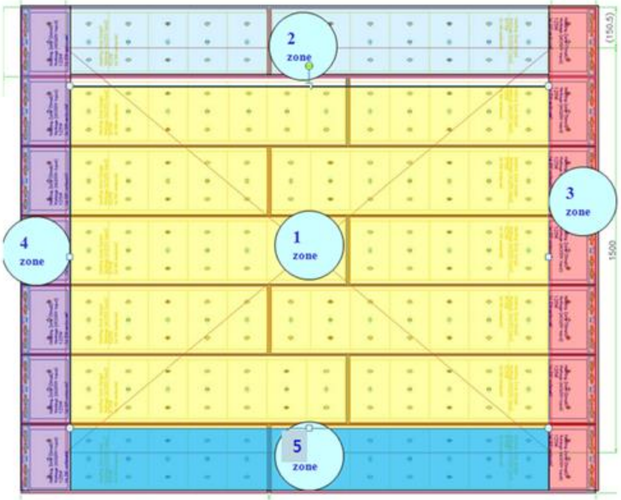

Fig. 14: 6G heater map

4.4. Design and manufacturing

In this thesis, the reduced control zone and self-temperature compensating technology applied to the sixth generation heater, and the side view and top view of the designed heater are shown in Fig. 15 and 16.

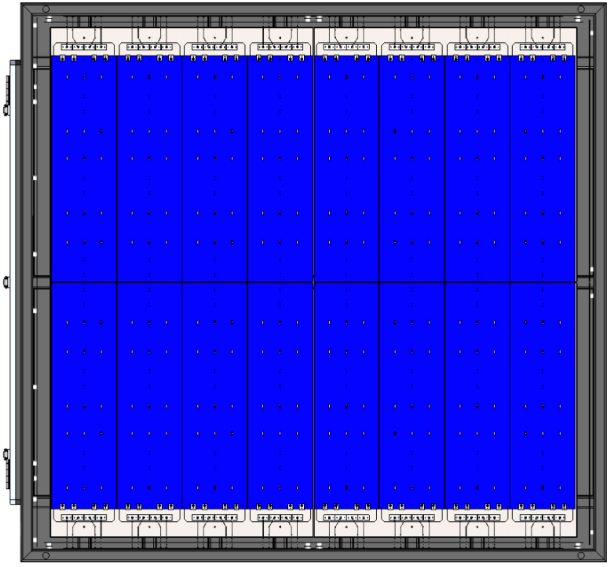

Fig. 15: Top view of designed 6G heater

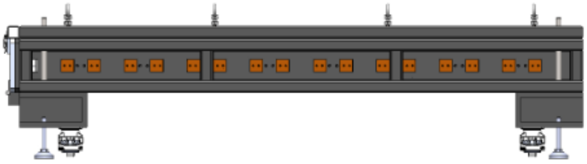

Fig. 16: Side view of designed 6G heater

The assembly and expectation drawing of finished product are shown in Fig. 17 and 18.

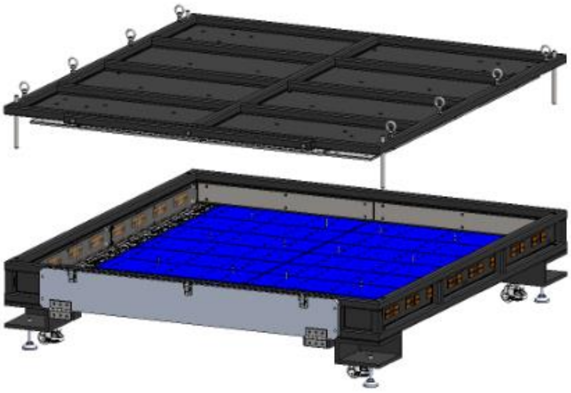

Fig. 17: Assembly drawing of finished product

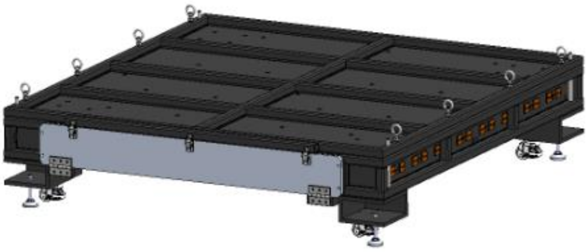

Fig. 18: Assembly drawing of finished product

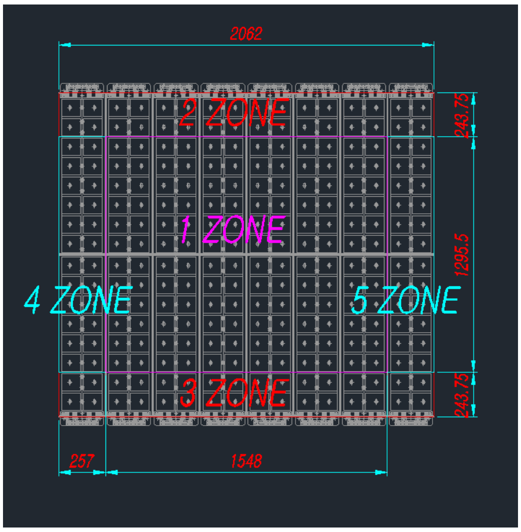

Fig. 19: Example of zone settings

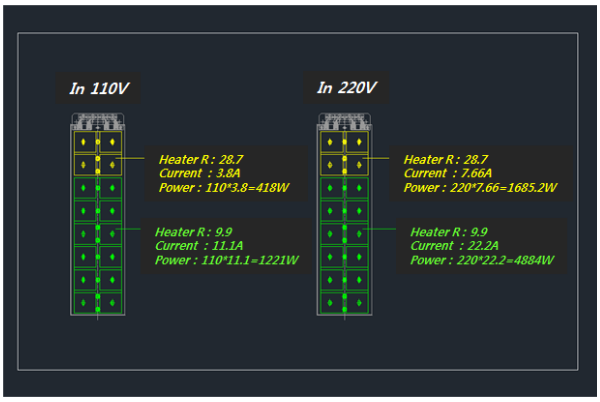

Fig. 20: Example of capacity settings

Table 3: Set heater zone-specific capacity

Zone No.	Item	In 110V	In 220V
1	Area[cm^2]	20054	20054
	Power[kW]	14.6	58.6
	Used Current[A]	133.2	266.4
	Power density[W/ cm^2]	0.73	2.92
2	Area[cm^2]	5026	5026
	Power[kW]	3.34	13.48
	Used Current[A]	30.4	61.28
	Power density[W/ cm^2]	0.67	2.68
3	Area[cm^2]	5026	5026
	Power[kW]	3.34	13.48
	Used Current[A]	30.4	61.28
	Power density[W/ cm^2]	0.67	2.68
4	Area[cm^2]	3329.4	3329.4
	Power[kW]	2.44	9.77
	Used Current[A]	22.2	44.4
	Power density[W/ cm^2]	0.73	2.93
5	Area[cm^2]	3329.4	3329.4
	Power[kW]	2.44	9.77
	Used Current[A]	22.2	44.4
	Power density[W/ cm^2]	0.73	2.93

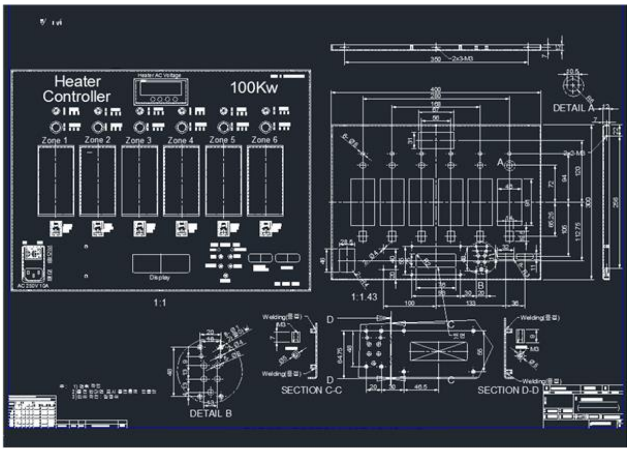

Fig. 21: Front panel of controller

Fig. 22: Developed heater for flat panel display manufacturing process

5. Conclusion

The number of control zones to ensure temperature uniformity has increased as display production technology has advanced and glass size has become larger. Also, development of SSR / SCR control unit for temperature control is required. Therefore, the temperature uniformity of 350℃ ± 5℃ was achieved using the control zone reduction and self-temperature compensating technology in this thesis, and the number of control zones was divided into five zones.

Acknowledgement

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Discussion

In this paper, we propose a heater with high temperature and high precision temperature characteristics which can be used in flat panel display manufacturing process. Future researchers will need to continue research on heaters that can improve display yield by applying to next generation FPD manufacturing process.

References

[1] Hirofumi Minami, Fusashige Matsumoto, Shinji Suzuki, “ Prospects of LCD Panel Fabrication and Inspection Equipment Amid Growing Demand for Increased Size”, *Hitachi Review*, Vol.56, No.3, (2007), pp.63-69, available online: http://www.hitachi.com/ rev/pdf/2007/r2007_03_108.pdf

[2] Joseph A. Tari, Cheryl M. Keiling, Jeffrey C. Richards, Sean Rudd, Charles Volkmann, “Liquid crystal display with temperature compensation”, US Patent, US20170221430A1, (2014), available online: https://patents.google.com/patent/US20170221430A1/en

[3] Hyeon Ki Park, Soo Min Kim, Joo Song Lee, Ji-Hoon Park, Young-Kyu Hong, Chan Ho Hong, Ki Kang Kim, “Flexible plane heater: Graphite and carbon nanotube hybrid”, *Synthetic Metals*, Vol.203, (2015), pp.127-134, available online: https://www.sciencedirect.com/science/article/pii/S0379677915000715

[4] Keith William Gaff, Keith Comendant, Anthony Ricci, “Thermal plate with planar thermal zones for semiconductor processing”, US Patent, US8461674B2, (2011), available online: https://patents.google.com/patent/ US8461674B2/en

[5] Keith William Gaff, Keith Comendant, “Heating plate with diode planar heater zones for semiconductor processing”, US Patent, US8624168B2, (2011), available online: https://patents.google.com/patent/ US8624168B2/en

[6] John Pease, “System and method for monitoring temperatures of and controlling multiplexed heater array”, US Patent, US9307578B2, (2011), available online: https://patents.google.com/patent/ US9307578B2/en

[7] Hyoung Keun Park, “A Study on the High Viscosity Photosensitive Polyimide Degassing and Pumping System”, *Journal of the Korea Academia-Industrial cooperation Society*, Vol.16, No.2, (2014), pp.1364-1369

[8] Hyoung Keun Park, “Study on the FPCS for Photoresist Coating of Semiconductor Manufacturing Process”, *Journal of the Korea Academia-Industrial cooperation Society*, Vol.14, No.9, (2013), pp.4467-4471